RICHEY

Effect of Clay on Strength of Concrete

Civil Engineering
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EFFECT OF CLAY

ON

STRENGTH OF CONCRETE

BY

JOHN JEFFERSON RICHEY

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

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JOHN JEFFERSON RICHEY

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering.

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Effect of Clay on Strength of Concrete.

It is only within recent years that concrete has come into its present extensive use as a building material. Ten years ago the cost of good cement was so high as to make its use very limited, but since that time, owing to the improved methods of manufacture, the price has been so much reduced that the importance and use of concrete have greatly increased. Because this material has so recently come into such general use, its properties and the conditions which affect its strength and efficiency are not very definitely known. To be sure, concrete is not as uniform a substance as steel or

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as binder even, and its properties, therefore, can not be so definitely known; yet there are some things which a natural asphalt will be better known than at present. One of these is the effect, upon the strength of the concrete, of a small per cent of clay in the sand or gravel.

It has been generally recognized that clay as an impurity decreases the strength of concrete, as is evidenced by the fact that most specifications require that the sand shall be clean, but to what extent clay is injurious to strength has not been definitely determined. Notwithstanding the importance of this matter, nothing in engineering literature could be found bearing on the subject. In view of these facts, the writer determined to make a series of

experiments to find, if possible, the relation between the per cent of clay in the material and the strength of the concrete.

Owing to the limited amount of time available for this work, the experiments could not be made as many as would have been desirable. It was early discovered that the effect of the clay may depend considerably upon the degree of wetness of the concrete, the amount of tamping, the ratio of the cement to the aggregate, and so forth; but it was decided to vary only the per cent of clay, the other factors being kept as nearly constant as possible.

In order the better to decide upon the amount and rate of variation of the clay, nine six-inch cubes of concrete were made for a preliminary test, three each of materials

containing 0, 6, and 10 per cent of clay, respectively. After being kept in water four weeks, these cubes were tested, and the results shown in Table I were obtained. These results indicated that a rate of variation of 6 per cent in the amount of clay would not be great, and as materials containing more than 12 per cent would rarely need to be used in engineering work, three grades of concrete were considered sufficient for the purpose in hand, containing, respectively, 0, 6, and 12 per cent of clay. Three similar cubes of each grade were made for each of three different sets to be broken at different ages, there being twenty-seven cubes in all, in addition to the nine in the preliminary test.

Besides the experiments to determine

the effect of clay on the crushing strength of concrete, further tests were made to discover the effect of clay on the tensile strength of Portland cement mortar, the object being to obtain a check upon the results of the experiments on concrete. For this purpose seventy-five briquettes were made, this set of five each of five different grades, containing, respectively, 0, 3, 6, 9, and 12 per cent of clay, the three sets to be broken at different ages.

The gravel used in the experiments was obtained from a bank near Watkins, and was such as is ordinarily used in this neighborhood for making concrete. It was run through a screen having a mesh of one inch, and the gravel was very dirty. The gravel which had been obtained on the

sand was then all turned and mixed well together, and tested to determine the amount of clay contained, which was found to be about 6 per cent. Most of the gravel was fine, a large per cent being no larger than peas or hazelnuts.

The sand was ordinary sand such as obtained from the same place as the gravel, and contained about 3½ per cent of clay.

Clean sand and gravel were obtained by washing the materials in a box with a hose and decanting the dirty water until the clay was all removed. Such a process, if many lots were treated, is a very laborious one and is not to be necessary nor at all economical for ordinary purposes.

The clay used was ordinary yellow clay, crushed into dust and passed through

a sieve.

The cement used throughout the various mixtures was Dexter A1 Portland, taken from a barrel newly opened.

The proportions of cement, sand, and gravel were, respectively, one, two, and six, by volume loose. The required quantities by weight to give these proportions were determined and the materials then measured by weight throughout the experiments. After the cement, sand, gravel, and clay were weighed out and mixed, water was added gradually and the working continued until the desired consistency was obtained. This consistency was the wettest at which the concrete would hold its form when squeezed in the hand, but it would not quake nor would water flow to the

lof after thorough kneading. It may be interesting to note that the more clay there was in the mixture, the greater was the amount of water required to bring the concrete to the same consistency.

The concrete was made up in small batches, and containing enough for three six-inch cubes, which were molded in heavy oak frames. Each cube was tamped in three layers with a heavy iron tamper, care being taken to give each cube, as nearly as possible, the same amount of tamping. After the cubes had stood for about twenty-four hours, covered with a wet cloth, the molds were taken apart, and the cubes were placed in water, where they were allowed to remain until ready to be tested.

The Olsen machine having a capacity of

200,000 pounds was used for crushing the cubes. The press furnished with a ball-and-socket device by means of which the bearing surfaces were made to fit themselves to the faces of the cubes to be crushed. This device was used to prevent the unequal distribution of the pressure which might otherwise result from the top and bottom faces not being exactly parallel. In order to insure still further a uniform distribution of the pressure, the precaution was taken to put a thin layer of plaster of Paris on the faces and allow it to set for a few minutes under pressure before crushing the cubes. In all cases the cubes were crushed in the position in which they were molded, that is, with the horizontal faces the top and bottom faces.

The results obtained in these experiments

were of standard size, made in gang molds and tamped by hand. [illegible] with the concrete cubes, to make the consistency and amount of tamping as nearly constant as possible. The remaining sand was moderately dry, and long and enough to cause water to flood to the surface after thorough tamping. The ratio of cement to sand was one to three by weight. The cement, sand, and clay were thoroughly mixed in the concrete, with the exception that the twenty-four briquettes broken at the age of two weeks were mixed with crushed quartz. A Richards machine with improved wedge grips was used for breaking the briquettes.

The results of the experiments are given in the following Tables:

TABLE I.

Results of Preliminary Tests to Determine the Per Cents of Clay to be Used in the Experiments.

Age of Cubes when Broken : 4 Weeks.

Ref. No.	Per Cent of Clay	Crushing Strength of 6-inch cube. Lbs.	Average Crushing Strength. Lbs.	Crushing Strength per sq. in. Lbs.	Relative Strength.
1	0	51800	55100	1530	100
2		54500			
3		59000			
4	6	43700	50100	1390	91
5		55000			
6		51500			
7	10	37000	38000	1055	69
8		37000			
9		40000			

TABLE II.

COMPARITIVE STRENGTH OF PORTLAND-CEMENT CONCRETE CONTAINING VARIOUS PER CENTS OF CLAY.

Ref. No.	Per Cent of Clay	No. of Cube	Crushing Strength of 6-inch cube Lbs.	Average Crushing Strength Lbs.	Crushing Strength per sq. inch. Lbs.	Relative Strength.
Age of Cubes: 1 Week.						
1	0	1 2 3	35600 40000 37400	37000	1030	100
2	6	1 2 3	31500 40000 37400	36300	1001	97
3	12	1 2 3	26000 25800 22800	24900	692	67
Age of Cubes: 4 Weeks.						
4	0	1 2 3	49000 51500 50500	50300	1398	100
5	6	1 2 3	62500 45000 57500	55000	1525	109
6	12	1 2 3	48000 45000 46300	46400	1287	92
Age of Cubes: 12 Weeks.						
7	0	1 2 3	90500 66100 71400	76000	2110	100
8	6	1 2 3	102000 100000 96400	99500	2760	131
9	12	1 2 3	69300 64500 68000	67300	1865	89

TABLE III.

COMPARATIVE STRENGTH OF PORTLAND-CEMENT MORTAR. CONTAINING VARIOUS PER CENTS OF CLAY.

Ref. No.	Per Cent of Clay	Breaking Strength of Standard Briquette. Pounds per square inch.			Relative Strength.
		Max.	Min.	Mean of Five.	
Age of Briquettes : 2 Weeks.					
1	0	225	185	202	100
2	3	295	250	267	132
3	6	310	245	280	138
4	9	340	295	318	157
5	12	365	305	333	165
Age of Briquettes : 4 Weeks.					
6	0	415	340	362	100
7	3	325	285	301	83
8	6	385	310	334	92
9	9	395	350	381	105
10	12	395	320	353	97
Age of Briquettes : 12 Weeks.					
11	0	485	395	451	100
12	3	560	470	506	112
13	6	545	490	521	115
14	9	565	475	522	115
15	12	560	520	547	121

The results, as a whole, are considerably different from those expected. In accordance with the general supposition that clay is an element of undesirable concrete, it was presumed that the cubes containing no clay would be much stronger than the others. However, this was not found to be the case; on the contrary, in one half of the experiments the cubes containing 6 per cent of clay were actually stronger than those containing no clay, and those with 12 per cent were almost as strong as the clean.

It would be unwarrantable to conclude from these few tests that a small amount of clay will, in general, add to the strength of concrete, or even that it will not be injurious. It should be re-

remembered that the experiments were made only with dry concrete, mixed in only one proportion. Under other conditions the results might have been somewhat different. It is generally recognized that the strength of concrete is affected by the amount of water used in mixing it, and the effect is doubtless greater for a small variation in the amount of water when the concrete is dry than when it is wet. Therefore, a partial explanation of the strange results of the tests may be found in the fact mentioned before, that the presence of clay-dust in the mixture required a slightly increased amount of water to bring the concrete to the same apparent consistency. The tamping also has much to do with the strength of the concrete, and it may be

interesting to note here that a considerable difference in the action under the hammering iron was observed between the clean concrete and that which contained clay. The latter seemed to compact much more readily and quickly than the former, which may have been due partly to the presence of the clay and partly to the slight excess of water mentioned above.

The results of the tests with mortar were still more remarkable than those with concrete, and they indicate that, under some conditions, the presence of clay in considerable quantities is not an element of weakness but of strength. The same explanation may be offered here, as with the concrete, that the presence of clay required an increased amount of water, and that the small difference in the per cent of

under may have had a considerable effect on the strength of the mortar, because of the fact that it was "dry" mortar.

Notwithstanding the above considerations, it is evident from the results of these experiments that the weakening effect of a small per cent of clay in concrete or mortar has been overestimated. Most specifications for sand require that it shall be practically free from clay or loam, and some require that there shall not exceed 1 per cent. Where clean sand and gravel are readily available, such requirements are all very well, but when the materials at hand contain a large per cent of clay it may be very undesirable to make the specifications so rigid. The effect of 1 or 2 per cent of clay would be almost nothing, and it would involve needless ex-

force to require the removal of the clay to that extent, since the labor of washing sand and gravel increases greatly as the amount of clay allowed to remain is decreased. It may happen that two grades of materials are available, the cleaner and costing considerably more than the other, and in this case the question is not how clean to wash the materials, but whether to use clean material at a high price or dirty at a lower price. If the effect of the clay is not great, it will be more economical to use the dirty material. The results of the experiments described indicate that clay to the extent of 6 per cent may, under some conditions, be an element of strength, and it is justifiable to conclude that, in general, that amount of clay would not decrease the strength of

concrete to any great extent. It may be said, therefore, that it is better to use sand and gravel containing as much as 5 or 6 per cent of clay than to incurr any considerable expense in securing materials containing no more than 1 or 2 per cent.

Note:

For the benefit of any who may wish to investigate this subject further, it is suggested that more satisfactory results would probably be obtained by the use of moderately wet concrete than that which is dry.

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